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NATIVE LIVESTOCK IN AFRICA.

THE PROBLEM OF OVERSTOCKING.

It has long been recognised that one of the most serious problems of the native livestock industry in many parts of Africa is overstocking. Its effects on vegetation and soils have been such that they have been thought in some parts of the country to be more serious than those of shifting cultivation. Overstocking has been defined as "the maintenance of animals on a piece of land to the detriment of its carrying capacity". The chief causes of this evil are said to be the cessation of tribal welfare which at one time enabled tribes to increase their grazing areas by penetration or conquest at the expense of neighbouring tribes, the persistence of lobola or bride price custom, and, more recently, the preservation of livestock by veterinary action. All these factors have tended to increase the livestock population and to intensify the damage to natural pastures in the native reserves. The areas where overstocking is particularly noticeable are not very large in extent: it is essentially a problem of local congestion. Where the problem does exist, however, little progress has unfortunately been made to solve it. The reason for this is that the whole of the native livestock industry is so closely bound up with native customs and habits of life that any reforms would mean revolutionary changes in habits of great social and religious significance. This is the main stumbling block to the evolution of any lines of policy which might be designed to counter the evil.

Before remedies can be applied it is essential to understand the native cattle owner's outlook towards his livestock. Domestic animals, to him, are family possessions and measures of social importance inherited within the family. They represent currency and investment. They are used as pledges for the good behaviour of women on marriage and for their proper treatment by the husband and his family. Breach of faith involves the return of these animals, and often of their increase. Sometimes they are exchanged for food or sold to pay taxes. They may be killed for ceremonial reasons but otherwise they are not usually disposed of. To the native, quantity of stock counts more than quality. Not much segregation or culling of beasts is practised so that the majority of stock appear degenerate, and for some period in each year are often in a state of semi-starvation and of little value for meat. We have

the paradox that in the midst of plenty natives in pastoral and semi-pastoral areas live under conditions of poverty because they do not yet know how to turn the products and increase of their herds into some more useful and fluid kind of currency. The purely economic conception of cattle held by Europeans does not coincide with the native's religious ideas. Overstocking will thus continue as long as native cattle-holding rests on a religious rather than an economic basis.

Again, certain native methods of livestock management may definitely be regarded as malpractices. For instance, the regular burning of dry grazing in order to promote or reveal the growth of young shoots not only weakens and destroys the roots of grasses and plants, but also hastens erosion. The herding of cattle into kraals at night not only leads to the trampling and complete destruction of grass around these enclosures, but also in the tracks leading to them, and the bare patches which result often act as foci of wind erosion. The system of herding at distant cattle posts or in the open does not encourage the use of animal manure and quite large quantities of manure are thus left to waste in the bush. Everywhere in those districts where overstocking exists there is evidence of trampling, overgrazing and consequent erosion and aridity. One of the worst causes leading to the accumulation of excessive and poor livestock is the communal use of grazing in the villages. Some pastoral tribes, in their natural state, had worked out certain systems of resting portions of the communal grazing, but these systems do not have the same force now, with the changes brought about by European rule.

It will be obvious from the above that certain of the existing native methods of cattle management will have to be modified by the tribes themselves if the natural agricultural resources of the districts in which they are practised are to be preserved.

It will be realized that there can be no simple solution of the problem of overstocking. Whatever line of action is taken is bound to interfere in some way or other with long established native customs. Take first the sale of excess male stock and barren cows. The object there would be so to change the attitude of the native towards his domestic animals that they become not tokens of wealth or a form of currency, but sources of income. The main obstacle to carrying this out successfully is the bride price which is generally paid in cattle or goats among both pastoral and agricultural tribes. If the change in the native outlook towards cattle could be made, then Africans might be taught to adopt such standard practices, which are at present often ignored, as the castration and eventual sale of excess males, supplementary feeding, calf-rearing, and, above all, the reduction of stock to reasonable numbers by the food available or anticipated.

Another method of approach is to encourage Africans to consume and sell more meat, milk and dairy produce. Once a native has learnt to regard his stock as a source of dairy produce he is likely to attach more importance to the productive value of each one of his cattle than to their mere numbers. Yet a third line of attack is to assist the native to find an economic outlet for his stock, by establishing more local butchers' shops and meat factories, which buy his cattle for cash, by teaching him better methods of preparing hides and skins, by introducing ghee manufacture and setting up small dairies for this purpose. Unfortunately it is mainly on the internal demand that the marketing and sales of native livestock products would depend, for in the world markets these would have little value. There is a market for hides, skins and bones, but the meat is hardly fit for export and the price which a company could afford to pay for livestock on the hoof would be a very low one. The chief obstacle in the way of these methods, which are being applied in varying degrees in several territories, is the conservatism of pastoral tribes—always much greater than that of agricultural tribes—and their lack of desire for cash.

There is one other way in which it might be possible to control overstocking, and that is by taxation. Such a measure might be justifiable on the grounds that a native in the past had certain duties towards his tribe, of which the payment of a tax is but the modern equivalent. Higher direct taxation for the pastoral tribes, the special taxation of surplus stock and a general stock tax, have all been suggested as possible forms in which taxation might be levied. It would seem that the levy of a specific stock tax as an additional tax might meet the case, for this would at least represent a rental for grazing. The machinery for collecting such a tax would, however, involve much additional administrative work.

The three main lines of approach to the central problem of livestock limitation—substitution of cash as bride-price, increased consumption, and increased sale—have been and are being followed. In certain parts of Africa, however, over-grazing has reached such a point that it is feared that pastures cannot be satisfactorily re-established. In these areas the compulsory culling of stock may have to be enforced by Government to save the land. Such compulsory destocking would mean difficulties for the administration and hardships for individual natives, but it is a better alternative than the abandonment of considerable areas of grazing land, which would in the end mean severer hardships. There can be no doubt that the solution of the problem of overstocking is of vital importance to the ultimate welfare of many of our African possessions. Every effort should be made, therefore, not only to bring this problem constantly before the public eye, but also before all the administrative services concerned, in order that it may receive the attention which it deserves.

THE AVOCADO—A HORTICULTURAL PROBLEM.

WILSON POPENOE.
(*United Fruit Company.*)

ABOUT the turn of the century—in 1901, to be exact—George B. Cellon of Miami, Florida began to offer budded trees of named avocado varieties to the horticultural public. Thus one more tropical fruit came out of the jungle stage of its existence. Since then, named varieties have multiplied—chiefly in Florida and California—until they number several hundred. A cooperative association of California growers, organized for the dual purpose of studying the cultural problems of the young industry and of marketing the fruit, looks back on 25 years of successful work. The crop marketed in 1938-1939 totalled more than 18,000,000 pounds of avocados.

Yet the avocado remains a dooryard tree throughout the Caribbean region. Sporadic efforts to place it on a higher plane have generally failed. No one factor is responsible for this. Distance from good markets has played its part. Unfavourable soil conditions have in many instances been fatal. Insufficient attention to the selection of varieties has retarded progress in several countries. And there have been other obstacles.

The time seems ripe for us to stand back and survey the situation in the light of what has been learned regarding avocados since those days, 40 years ago, when Cellon singled out two dooryard trees near Miami, called them Trapp and Pollock, propagated them by budding, and placed them on the market with what impressed many persons as extravagant claims regarding the commercial possibilities of avocado culture—claims which subsequent experience has fully justified.

Early History.

We have no proof that the Very Magnificent Lord Don Cristobal Colón saw the avocado in the course of his voyages of discovery. It was not then grown in the West Indies, where most of the Great Admiral's time was spent. But Martin Fernandez de Enciso, whom Sir Clements Markham characterised as a "cartographer, a good observer with the gift of lucid description" saw it on the mainland near Santa Marta, Colombia, as he coasted along those shores with one of the first Spanish expeditions; and he described it in his "Suma de Geografia" which was published at Sevilla in 1519. Thus was the avocado made known to Europeans—and we might add, with a dignity befitting its merits, for Enciso's "Suma de Geografia", one of the first published accounts of the New World, has become a classic of classics.

Subsequent travellers and historians—Oviedo, Cieza de Leon, Cervantes Salazar, Acosta, and others—noted the presence of this fruit from Mexico to Peru, and in some instances described it in detail, always in flattering terms. Oviedo, for example, wrote in 1526, "On the mainland are certain trees called pear trees, but they are not like those of Spain, though held in no less esteem; rather is their fruit of such a nature that they have many advantages over our pears".

From the tales of the early voyagers we are able to picture fairly clearly the distribution of the avocado in tropical America at the time of the Conquest. As has already been mentioned, it definitely was *not* present in the West Indies. It was abundantly grown in Mexico, extending almost to the Rio Grande on the north. It was a popular fruit among the Maya tribes of Guatemala, and was cultivated by the Indians of Nicaragua. Cieza de Leon recorded its presence in the western valleys of Colombia. Not long after the Conquest the Inca Garcilaso de la Vega told how it had been carried from the province of Palta (in what is now Ecuador) to the warm valleys near Cuzco by Tupac Yupanqui, some time between 1450 and 1475.

It is fair to assume, therefore, that the avocado was known throughout the territory between northern Mexico and central Peru; but there is no evidence that it was known in the eastern part of South America. On the other hand, it seems highly probable that it was not known east of the Venezuelan Andes.

Origin of the Cultivated Avocados.

With this understanding of the distribution of the avocado at the time of the Conquest, it is in order for us to ask, "Whence came these cultivated or semi-cultivated trees which were seen by the first voyagers? Were they derived from a wild form, still to be found somewhere between Mexico and Ecuador? If so, where does it grow and what is it like?"

This problem is complex, for we are concerned not with a single group of avocados, obviously of common origin; we are concerned with three groups, which may or may not have had a common origin. These three groups, which were recognized and characterised as early as 1653 by Fray Bernabe Cobo, in his *Historia del Nuevo Mundo* are to-day known horticulturally as the West Indian, Guatemalan, and Mexican races. Any investigation of their origin which we may attempt to carry out, brings us up against the more technical problem of their botanical classification and relationships.

Is more than one species of *Persea* involved in the origin of the cultivated avocados of to-day? It is my personal opinion that this question must be answered in the negative. Let us review the situation briefly:

Gaertner, in 1807, described *Persea gratissima*, the avocado. In recent years it has been shown that Miller had previously described it (1768) under the name *Persea americana*, and on grounds of priority this is the name now accepted by most American botanists.

In 1831 Chamisso and Schlechtendahl described *P. drymifolia*, thus raising to specific rank the Mexican race of avocados. This has not been generally accepted: more recent and exhaustive study, especially that of Sidney F. Blake of the United States Department of Agriculture, reduces this race to the status of a botanical variety of *P. americana*. Personally I am not even willing to grant it that distinction; in my opinion the Mexican avocados constitute a geographical form of *P. americana*—but I am not a taxonomist and have no right to be heard.

At the time Blake made his "Preliminary Revision of the North American and West Indian Avocados" (*Journ. Wash. Acad. Sci.*, Vol. X, No. 1, 1920), he discovered that the horticultural variety Trapp—then the principal one cultivated in Florida—differed from all others of which he had material for study, in that the floral parts were almost glabrous. Since this constituted a botanical distinction Blake made a new species calling it *P. leiogyna*. Later he had opportunity to see specimens, not of Trapp, which exhibited this same characteristic, and in recent discussions he has expressed to me the conviction that *leiogyna* is not a good species.

This, then, brings us to the conclusion that all known avocados are referable to *P. americana* from which the Mexican race can be distinguished as a botanical variety, *drymifolia*, if one chooses. Though again I must say that extensive observation in the field convinces me that there are insufficient grounds for separating the Mexican race, botanically, from the others.

We are not here concerned with *Persea schiedeana* Nees, which some authors have considered a botanical variety of *P. americana*, but which in the light of more recent study is obviously entitled to the specific rank given it in 1836. This avocado-like fruit is the *chinini* of southern Mexico, the *coyó* and *chucte* of Guatemala, the *yás* of Costa Rica.

Our problem therefore boils down to this: Where is *Persea americana* found in an indigenous condition, and what is the wild tree like?

During my travels of the past 25 years, I have seen wild avocados of three distinct types in tropical America. It is my belief that at least two of these represent wild forms of two of the horticultural races, the Mexican and the Guatemalan. Regarding the prototype of the third race—the West Indian—I am not so clear.

In southern Mexico, particularly on the slopes of the volcano Orizaba, there occurs abundantly a wild avocado which bears small thin-skinned fruits, purple or green in colour. The foliage and bark of the tree are characterized by a strong anise-like scent. This geographical form of *P. americana*, which I have called the wild avocado of Orizaba (cf. Yearbook of the California Avocado Association, 1935) can without any stretch of the imagination be considered the wild prototype of the Mexican avocado, the *P. americana drymifolia* of Chamisso and Schlechtendahl. It differs from the cultivated forms only in the size of its fruit.

On the summit of the Chichoy mountains in central Guatemala not far from the town of Tecpan, there grows another wild avocado, so much like the cultivated forms of the Guatemalan race as to leave small room for doubt that it is in fact the prototype of this horticultural group. This geographical form—which I have called the wild avocado of Tecpan—grows at higher elevations than any other avocado known to me. It occurs in the forest surrounded by pines, oaks and the stately *Cupressus benthami*. Its foliage, which is devoid of anise-like odour, resembles that of cultivated varieties of the Guatemalan race, while its fruit differs in no respect except its smaller size, and the relatively small amount of flesh. The "shell" is so hard and woody that it cannot be cut easily with a knife.

This leaves only the West Indian race to be accounted for. I have already explained that this does not come from the West Indies. I have studied no wild form which can with confidence be claimed as its prototype. Near the town of Boquete, in the Republic of Panama, I have seen on the slopes of the Chiriqui volcano at elevations of about 5,000 feet, a few trees which had every appearance of being indigenous and which bear avocados resembling very closely many West Indian seedlings. And again, on the slopes of the Sierra Nevada de Santa Marta, in Colombia I have seen the same sort of thing in great abundance. But I have always had a suspicion that these were escapes. If they are not, then the West Indian race has its native home in Panama and Colombia, which, in the light of what we know of its history, would seem logical.

In the lowlands of the Atlantic side of Honduras, and again in the vicinity of San José de Costa Rica, I have seen a wild avocado—which I have called the wild avocado of San Isidro—which *may* be the prototype of the West Indian race, though if this is true it argues a long period of cultivation; for the differences which exist between this wild form and the cultivated West Indians are considerable, though perhaps not unsurmountable. The wild avocado of San Isidro has the anise-like odour which characterises the Mexican avocado, and which never occurs in the cultivated West Indians. And it has the thick "shell" of the Guatemalan race—thicker and more woody than is common in cultivated forms of the West Indian.

Development of Commercial Varieties.*

I have tried to sketch the background—so far as we know it—of the present-day commercial varieties cultivated in California, Florida, and a few other regions. Now as to the origin of the varieties themselves:

They are—without exception I believe—chance seedlings, chosen for a sexual propagation because of their desirable commercial characteristics. Some of them are "pure-blooded" representatives of the West Indian race, some are Guatemalan, and some are Mexican. Some have characteristics which lead us to believe that they are natural crosses between two of these races. This group is perhaps the most interesting of all, and the most promising. The major purpose of this paper, in fact, is to point out the possibilities of some of these crosses for the West Indies.

As stated above, no varieties on the market to-day are the result of crosses by man. We therefore do not know the parentage of those varieties which we consider crosses, except on one side. We do not in all cases know even this. Take Fuerte, for example—the variety which to-day makes up more than 75 per cent. of the total acreage planted under avocados in California. Because its growth is unusually vigorous; because its foliage has the anise-like odour which is characteristic of the Mexican race, while its fruit is thicker skinned and more suggestive of the Guatemalan—for these and a few other reasons we have always assumed Fuerte to be a Mexican-Guatemalan cross. But we know neither its seed-parent nor its pollen-parent. It was discovered in a garden in Atlixco, Mexico, already a full grown tree with no recorded history. The presence of numerous trees of the Mexican race in that neighbourhood, as well as numerous trees of the Guatemalan race, made our hypothesis tenable. Further evidence was later acquired through the behaviour of Fuerte seedlings.

Aside from Fuerte, California cultivates, in the main, varieties of the Guatemalan race and varieties of the Mexican race. In Florida, the situation is different.

Trapp and Pollock, the first two varieties placed on the market in that State, are typical West Indians, presumably to be traced back to Cuba since most of the West Indian seedlings found in Florida originally came from that source. In the years immediately following the introduction of Trapp and Pollock, several other West Indian varieties were placed on the market. Then, through the presence of a few trees of Guatemalan origin in the Plant Introduction Garden maintained by the United States Department of Agriculture at Miami, West Indian-Guatemalan crosses began to appear upon the scene.

We assumed, at least that they were crosses. The fruit was thicker skinned than was commonly true of the West Indians, and it matured considerably later. This latter characteristic immediately stamped the crosses as of great promise, for the chief commercial characteristic lacking in the Florida avocados previously cultivated was a ripening season which would take them out of competition with Cuban seedlings. The latter ripen from July to September, though an occasional one will hold part of its crop into October or even November. But the West Indian-Guatemalan crosses ripen much later enabling the grower to place fruit in northern markets during the winter months when high prices are realized. Pure-blooded Guatemalan varieties, many of which have proved highly successful in California, do not thrive so well in Florida. Out of 23 selections which I made in Guatemala during the years 1916-1917, and which were distributed for trial in Florida by the United States Department of Agriculture, I do not believe a single one has achieved any commercial importance, though Itzamna has given a good account of itself in several places.

In addition to these West Indian-Guatemalan crosses, which are assuming greater and greater commercial importance in Florida, there is one variety which, to me, has always possessed peculiar interest. This is Gottfried, believed to be a West Indian-Mexican cross, the only one which has ever come to my attention. Gottfried ripens early, wherein it resembles the Mexican. Its fruit, though considerably larger than that of any pure-blooded Mexican which I have seen,

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* The Editor is indebted to Mr. R. O. Williams, Deputy Director of Agriculture, Trinidad, for preparing the following note which deals with varieties of avocado grown in Trinidad:—

"A good deal of attention has been paid to the improvement of avocados in this Colony. Selections of local types have been made by the Department of Agriculture and the Imperial College of Tropical Agriculture; the latter also have investigated the selections for good storage qualities. Introductions have also been made by the Department of Agriculture and others of good West Indian, Guatemalan and Mexican varieties, and hybrids of these.

The following is a list of those under cultivation:—

Local varieties:—
St. Ann's, St. Clair, River, St. Joseph No. 1, St. Joseph No. 2, Lenegan and Macqueripe No. 2.

Introduced varieties:—
West Indian ...Pollock, Rudder, Simmonds, Butler.
Guatemalan ...Panchoy, Queen, Benik, Nabal, Dickinson, Anaheim, Dunedin.
Mexican ...Puebla, Blake, Mexicola.
West Indian + Guatemalan Collinson, Winslowson, Lula.
Mexican + Guatemalan Fuerte.

Of the early introductions Pollock is outstanding. Trapp was found to be worthless! The later introductions which show particular promise for extending the avocado season are Collinson and Winslowson; a number of recent introductions have not fruited as yet."

has the same thin skin, the same nutty flavour. The tree has leaves which look like those of the Mexican race, and they have the characteristic anise-like odour.

So much for the make-up of those avocado varieties which are commercially planted to-day in California and Florida—the two chief centres of avocado culture. Many of these varieties, during the past 25 years, have been planted experimentally in various parts of the American tropics. What can we learn from their behaviour? What are the lines along which our future efforts should be directed?

California and Florida Varieties in the Tropics.

Before going into this matter, let us consider for a moment the situation around the Caribbean with regard to native seedlings. These are all of the West Indian race. Some regions possess fine specimens of this race, others poor ones.

Cuba has many excellent seedlings, particularly on the limestone soils of the western portion of the Island. The situation is much the same in Jamaica, and in parts of Haiti. Puerto Rico is characterised by few trees of inferior type, and it is my opinion that this same situation holds in a general way for the Lesser Antilles. Occasional exceptions occur, no doubt, but so far as my observation extends the native seedlings of the lower islands do not compare, on the whole, with those which grow on the limestone soils of Cuba and Jamaica.

Upon the Spanish Main there are excellent avocados to be seen in the neighbourhood of Santa Marta, Colombia. The coastal region of Venezuela, on the other hand, has few choice ones and no great abundance of mediocre ones, Westward from Santa Marta there is no coastal region famous for its fine avocados until one reaches Yucatan. This is not saying that avocados of fair quality are not to be found here and there.

With the development of commercial avocado culture in California and Florida, horticulturists around the Caribbean awakened to the possibility of extending the short ripening season of their native West Indian seedlings through planting Guatemalans and Guatemalan-West Indian crosses. Puerto Rico was one of the first regions to go in for these new sorts. During my later years in the Department of Agriculture at Washington—somewhere around 1920—we made numerous experimental shipments of budded trees to Puerto Rico. But when I visited that island recently I learned that little has come of the effort. In fact, there seem to be very few areas in Puerto Rico where avocados of any kind are happy. The region of Yauco on the southern side of the Island is one notable exception. I blame the trouble on heavy soils, which in turn mean lack of good drainage and a ration in most instances. If there is one thing the avocado simply will not tolerate it is wet feet.

Cuba had its fling, and at approximately the same time as Puerto Rico. Cuba is an avocado island, and at one time there seemed to be a strong probability that one or two of the Guatemalans, and several of the Guatemalan-West Indian crosses, would attain commercial importance there. But something happened. I don't know just exactly what it was. Perhaps a mixture of politics and bad drainage, with emphasis on the latter.

In more recent years some of these same varieties have been planted in Jamaica, in Haiti, in Trinidad, in Colombia and elsewhere around the Caribbean. It is too early, in most cases, to talk of results. But I can speak with confidence regarding what has been done in one fairly representative region — the north coast of Honduras. Here, at Lancetilla Experiment Station, we introduced in 1925 and subsequent years, an extensive collection of varieties including Guatemalans, West Indians, Guatemala-West Indian crosses, one Guatemalan-Mexican cross (Fuerte), and the one known West Indian-Mexican cross, Gottfried.

As far as I can judge, climatic conditions on the north coast of Honduras are not unlike those of the wetter parts of the West Indies. We are at sea level and we have a dry season of one or two months' duration at Lancetilla proper; one of three or four months at our substation Quebrada Seca, some 40 miles up the Ulua valley from the coast. Annual rainfall at Quebrada Seca is in the neighbourhood of 60 to 70 inches; at Lancetilla it varies from 125 to 175 inches.

Pure-blooded varieties of the Guatemalan race have been a complete failure here. This is not saying that the trees have not, in several cases made good growth; nor is it saying that they have not borne fruit. But I am convinced that it is a mistake to grow Guatemalans at sea level in the tropics. This is a highland race, and when taken down to the coast the fruit almost invariably loses its flavour and quality. We have grown such varieties as Nimlioh, Panchoy, Queen, and Linda: all mature their fruits very late in the season, ripening from November to January in the main, but all are disappointing and all show a tendency to produce small crops. They are not satisfactory.

Pure-blooded varieties of the Mexican race serve no purpose here, unless one might argue that their nutty flavour is a desideratum. Their value lies chiefly in their resistance to frost. But we have tried them, mainly out of curiosity and they have not done well. Like the Guatemalans, they belong to the highlands.

Fuerte, the leading commercial variety of California, is presumably a Guatemalan-Mexican cross. In the light of what has just been said regarding the behaviour of these two races at sea level in the tropics, how could one do otherwise than predict a gloomy future for Fuerte in such

a place as Lancetilla? We have grown it for 15 years: the trees vegetate well, they blossom freely, but they produce few fruits and these of poor quality. Even the southern part of Florida is too tropical for Fuerte. This is distinctly a subtropical avocado. When grown in the tropics, it must be at high elevations. It might prove very useful in the Andes.

And now we come to the brighter side of the picture: the West Indian-Guatemalan crosses. This is, in my opinion, the group which will in time place avocado culture in the West Indies upon a new and sounder footing. Even with the varieties available to-day, much can be done; and new varieties can and will be produced in large numbers.

The Future.

Collinson, Winslowson, Collinred, and Lula have all done well in Honduras, and they have done well at several other places in tropical America. Perhaps they are not ideal varieties: from the commercial standpoint I am willing to concede that they are not. But they show what can be expected of this cross. It offers, in my judgment, the one real hope of producing in the Caribbean region avocados of good commercial quality at that season of the year when avocados are most desired—the winter months.

Viewing the matter from another standpoint, here is an opportunity to lengthen the period during which avocados are available in the West Indies for local consumption. This is a matter of greater importance than appears at first glance. For the avocado as a source of human food is not yet fully appreciated in the Islands. We hear much talk these days of over-population. How are people to be fed? If they are to be largely dependent upon what they can produce—as most certainly is desirable—then we need crops which (i) will give maximum yields of food per acre (ii) which are available during as many months of the year as possible and (iii) which people will eat, and like.

When we horticulturists can offer avocados during six or eight months of the year, when we can supply varieties which contain 12 or 14 per cent. of oil (this is by no means asking too much), we shall be making a real contribution towards the solution of one of the grave problems confronting some of the Islands. The one serious obstacle which I see is the admitted failure of the avocado to thrive on certain soils, or in certain areas. Whether this is a matter of drainage, whether it is due to root diseases of which we still know little, or whether it is due to something about which we still know nothing at all, it is a real and serious obstacle to wider and more successful cultivation of the avocado. So far as I have been able to observe, there is no trouble when avocados are grown on sloping lands derived from soft limestone. There is no trouble when they are grown on sandy loams and clay loams if these are well drained and not subject to flooding. But put the avocado on stiff, impermeable clays; put it on the best sandy loams and flood it for even a few days—in other words, cut off the oxygen supply to its roots—and if my experience is any guide, you will soon see the younger branches beginning to die back and the end is in sight.

To avoid further disappointment, let us put our avocados on the right kind of land; and let us then devote serious attention to the development of new varieties of the West Indian-Guatemalan group, varieties which will give us fruit of excellent quality and extend the present avocado season in the West Indies by three or four months at least.

SHADE TREES IN UGANDA AND THE CULTIVATION OF COFFEE AND TEA.

It has been shown by A. S. Thomas (*E. Afr. Agric. J.* 1940, 5: 287-93, bibl. 4) that in most cases coffee does better under shade and it is, of course, a forest plant in nature. The type of shade preferred is that which is evenly distributed and with branches high above the tops of the coffee bushes. Shade trees should be grown in succession or in mixture. When these have to be thinned out—for close planting at first is obviously necessary—the trees can be ringed instead of felled; the tree then dies as it stands, disintegrates gradually and no harm is done to the bushes below. The practice also reduces root disease risks, since *Armillaria mellea* will not attack roots deficient in starch. In selecting shade trees many varieties otherwise suitable are put out of competition on account of their strong surface rooting system competing with the coffee roots. *Erythrina abyssinica* is suggested as a likely shade tree since it succeeds in conditions too dry for many other shade trees, is easily established from large woody cuttings and is well adapted to pollarding. A list is given of local trees under which coffee will flourish; these should be retained when land is being cleared for planting. Most useful of all are various *Ficus* especially *F. Thonningii*. They can be grown in the position required from large cuttings and besides supplying shade can provide additional income to the peasant as a source of bark cloth. Of exotic trees *Hevea brasiliensis* is a useful shade for *robusta* coffee in Uganda where its growth is not so vigorous as in a really tropical climate; if the price of rubber rose the tree could be tapped. A number of other non-indigenous trees used for shade in other countries are discussed. Tea requires no shade but needs windbreak protection from drying winds which spoil the flush. *Grevillea robusta* is suggested since it casts little shade.—(*Imp. Bur. of Hort. & Plant. Crops, Hort. Abstracts*, Vol. X, No. 2, Abs. 688, pp. 165-66, 1940.)

BANANA CULTURE AROUND THE CARIBBEAN.

By Wilson Popenoe.

[*The following article is an English translation of "Cultivo del Banana en la Zona del Caribe," published as Nos.* 113 *and* 114, *Seria de Agricultura, in the "Boletin de la Union Panamericana," Washington, June and July,* 1936.]

The markets of the north temperate zone—in other words, those of Europe, Great Britain, the United States, and Canada—consumed annually during the past five years, between 75 and 100 million bunches of bananas. Of this total amount, six or seven million were grown in the Canary Islands, one to three million on the west coast of Africa, some two million in Brazil, four to eight million in Mexico, and two to four million on the Pacific coast of Central and South America. The remaining 56 to 82 million were grown in the Caribbean region, which has long been, and doubtless will for some time remain, the world's chief centre of banana cultivation. Honduras alone produces as many as 30 million bunches in a good year; Jamaica as many as 24 million.

From an agricultural standpoint, one of the most interesting features of this enormous fruit industry is the fact that it is based predominantly on a single variety of bananas—the Gros Michel. While bananas shipped north from the Canaries, the west coast of Africa, and Brazil are of the Cavendish or dwarf variety, and while this and a few others are exported in a small way from the Caribbean region, it can truthfully be said that the world's bananas business is based upon Gros Michel. This is the more remarkable when one stops to reflect that there are several hundred banana varieties in cultivation, some of which are highly esteemed in the particular regions where they are grown.

The pre-eminent position of Gros Michel has been achieved because of its unusual combination of desirable qualities. From the grower's standpoint it is satisfactory because, under suitable conditions of climate and soil, it yields heavily. The men concerned with handling and shipping the fruit find it superior because the compact nature of the bunch renders it less liable to bruising than is the case with many other varieties. Jobbers like it because it colours up well on ripening and the individual fruits show little tendency to fall from the bunch. The retailer prefers it because of its attractive appearance when displayed in his shop and the consumer likes it because it adds to the appearance of his table and because of its excellent flavour.

Other bananas may exist which equal or excel Gros Michel in one of these points, but it is rare to find so many good qualities combined in a single variety. For this reason, added to the fact that markets are conservative and it is always difficult to supplant a well-known product with a new one, Gros Michel will almost certainly continue to be the leading banana variety for many years to come. Indeed, I wonder if it is not, when judged from the standpoint of actual volume, the most important single fruit variety in the world?

The wide range of climatic and soil conditions under which the Gros Michel banana is grown in the Caribbean region renders impracticable a simple treatment of its planting and cultivation. The purpose of this paper, therefore, is not so much to set forth detailed directions, as to lay down fundamental principles which should guide the planter when interpreted in the light of his own particular conditions of soil, climate, labour costs, and so forth.

A few facts about the Gros Michel banana.

It goes without saying and it applies to all crops that the successful grower starts with a fundamentally sound conception of the plant he is cultivating, its nature, and its requirements. This does not imply that he has to be a plant physiologist or that he must acquaint himself with many technical details. What I mean is simply this: he must understand his crop the way a breeder of fine race horses understands his animals; he must feel almost instinctively when his plants are suffering and must know how to meet their needs.

Many of us who come to the tropics from the temperate zone have been trained to think of fruit trees as slow growing, hard-wooded plants with relatively great capacity for withstanding unfavourable conditions of environment as well as bad treatment generally. It takes us some time to realize how different the banana plant is from the fruit trees with which we have been familiar. It is not a tree at all: it is a gigantic herb capable of almost prodigious cell activity and therefore requiring abundant and constant supplies of water, heat, and plant nutrients, particularly nitrogen. It is sensitive to its environment in a high degree. It feels the shock of drought or of cool weather promptly and definitely, and reflects it in its growth and fruit. One cannot overemphasize the importance of keeping its life-processes going at full speed every day in the year if good results, in terms of quality and quantity of production, are desired.

It is surprising how much variation exists with regard to root development of the banana plant on different soils. If grown on heavy clay, so that oxygen is abundantly available only in the uppermost few inches of soil, practically all the feeding roots are confined to this zone. In extreme cases they may only extend laterally to a length of not more than five or six feet, while

the so-called anchor roots—those which go down vertically from the base of the plant—may only penetrate to a depth of two feet. In contrast to this a plant growing on deep fine sandy loam may send out lateral roots to a length of 15 feet or even more, while its vertical roots may penetrate to five or six feet. With this more extensive root system the plant not only is able to draw upon a much larger area for nutrients, but also it is prepared better to resist drought, since it has a larger proportion of its feeding roots at deeper, moister levels than in the first case.

The time which transpires between planting and maturing of the crop varies with climate, soil, and several other factors. Under the conditions of Honduras, for example, it takes six to eight months on heavy clays, but about nine or ten months on lighter soils, for young plant to reach the stage known popularly as "shooting"; *i.e.*, the appearance of the blossom. From blossoming to maturity of the bunch, the time varies in accordance primarily with weather conditions. During the warmest season of the year the maturing period may be as short as 75 days, while during the cool season it may be as long as 115 days.

The length of the growing period, as described above, applies only to first generation plants. Subsequent generations require considerably longer to develop. From the time the sucker first comes through the ground—what is commonly termed the "peeping" stage by banana men—to the time of blossoming, averages about 17 months on light soils in Honduras and as much as 20 months on heavy soil.

A "bunch" of bananas as commercially accepted, consists of nine hands or more. Under optimum growing conditions bunches of less than nine hands are uncommon; but where climate and soil are unfavourable, or where the planter has neglected to provide adequate agricultural treatment, bunches of eight and even of seven hands are frequently produced; sometimes even of six. Based upon a large number of bunches examined in Honduras, the average number of individual fruits, or "fingers" per bunch varies as follows:—

6	hands	....	....	77	fingers.
7	,,	....	....	99	,,
8	,,	....	....	122	,,
9	,,	....	....	145	,,
10	,,	....	....	167	,,
11	,,	....	....	190	,,
12	,,	....	....	213	,,
13	,,	....	....	235	,,
14	,,	....	....	258	,,

Prices paid to growers by the large shipping and marketing companies are based upon the standard nine-hand, or "count" bunch; eight hand bunches usually are worth three-fourths as much as a nine; seven-hands are worth half as much; and six-hands one-fourth as much. It is therefore customary to calculate production in terms of count bunches. From this figure, in turn, may be calculated an index known as the "count bunch ratio", which is often useful to the grower as a measure of his agricultural efficiency. Let us say, for example, that a certain area in a certain year has produced and shipped 607 bunches of nine hands or better (count bunches), 136 of eight hands, 75 of seven hands, and 41 of six hands. We reduce all these to count bunches as follows:—

9's	607	×	1	607
8's	136	×	$\frac{3}{4}$	102
7's	73	×	$\frac{1}{2}$	36.50
6's	41	×	$\frac{1}{4}$	10.25
	857			755·75

Our 857 bunches (commonly termed "stems" by banana men) are therefore equal to 755.75 "count bunches". Dividing the latter figure by the former, we get .882, the "count bunch ratio", which for convenience would commonly be stated as 88. Through long familiarity with climate, soil and other conditions of his farm, the planter learns what can be expected not only of the area as a whole, but of each section or other unit. The count bunch ratio of 88, therefore, taken in conjunction with the total production of 756 counts (approximately), would by comparison with the records of previous years, tell him whether his farming is getting better or worse—unless he can blame poor results on floods, winds, or other factors beyond his control. It may be said, in passing, that a count bunch ratio of 88 would be considered highly satisfactory in many parts of the Caribbean region. On rich, new lands under adequate rainfall, ratios of 92 to 95 are often reached and maintained for several years. In dry climates, especially if the soils are heavy and there are strong winds which whip the leaves of the plants to shreds during a portion of the year, ratios of 75 to 80 might be as good as one would be warranted in expecting. The first or "plant" crop usually averages eight or ten points lower in count bunch ratio than the second year's production; after this, the ratio remains fairly uniform for some years if cultural conditions are favourable, but drops off gradually in regions such as the south coast of Jamaica. After three or four crops have been harvested, it may be necessary to plough and replant the area in order to bring quantity and quality of production back to the maximum.

Climate.

The ideal climate for banana cultivation would be one devoid of extremes of temperature and with frequent light rains falling throughout the 12 months of the year. Actually we must content ourselves with something less than this in most regions where bananas are grown commercially to-day.

So far as temperature is concerned, there is probably no region around the Caribbean with a maximum too high to permit successful banana growing, though there are probably a few where it sometimes goes higher than the grower would

desire. For example, in the banana zone near Santa Marta, Colombia, temperatures approximating 105° F. occur during the dry season. Naturally, they are accompanied by low relative humidity and the combination serves to increase the difficulty in supplying adequate irrigation.

At the other end of the scale, in regions where the thermometer goes to 50°F. or below, difficulty will be experienced from "chilling". This term is used to express the effect of low temperatures upon the ripening of the banana. There is no need here to enter into details regarding what is, at best, a highly complex and difficult subject. Suffice it to say that chilled fruit is not marketable, and, if temperatures of 50 or slightly less occur many times during the year, they seriously reduce the planter's profits.

Even above 50 degrees, low temperatures are of interest to the planter. A protracted period—for example, a week or more—of cool dark days with nightly minima of 60 degrees will so retard the development of his fruit that the planter will find on subsequent fruit cuttings that he has fewer mature bunches than he had expected. If the cool weather continues, some of his fruit may even commence to ripen on the tree before it has filled out to normal grade. (The term grade, as will be explained later, is commercially used to express fullness or diameter of the individual fruit.)

The ideal climate, therefore, can be postulated as follows, so far as temperature is concerned: one in which minima are rarely below 65 and never below 60, while the maxima are rarely above 95. A long season of cool weather is a distinct disadvantage.

Rainfall, where not adequate during certain seasons of the year, can fortunately be replaced, to a large degree, through irrigation. I say "to a large degree" intentionally, for it seems rarely true that regions where irrigation must be practised during most of the year produce as large fruit as is grown in regions of adequate rainfall. By adequate rainfall is meant rains of such frequency that the surface soil under the normal shade of a banana plantation never really gets dry. Obviously, bananas can be grown without irrigation even in regions where there are occasional dry spells of several weeks' duration, but this is not an ideal situation. What the plant really wants is constantly moist soil, without, however, standing water anywhere within the reach of its roots.

There are many regions around the Caribbean where rainfall is so definitely seasonal in character that irrigation is necessary if bananas are to be grown at all. There are areas—many of them—which normally experience a dry season of one to three or four months' duration. In some of these the planter has to face the question, "Shall I gamble on the weather and expect to lose fruit during these years when the dry season is long, or shall I spend the money required to protect myself during drought by installing irrigation on my farm?" In answering this question the planter must utilise not only the rainfall records of previous years, but also an accurate knowledge of his soil; for, other things being equal, bananas will stand more drought on deep loams than on either of the extremes—heavy clays and light sandy soils.

Naturally, the facility and expense of obtaining water for irrigation and getting it on the land are also major factors. As a guiding principle, it is perhaps safe to state that in any region, no matter how good the soil, where droughts, eight weeks or more in duration, can be expected annually, irrigation should be given consideration.

It remains only to mention one more climatic factor—wind. This must be considered under two separate heads, since the steady trade winds, such as those which blow across the islands of the Caribbean during certain portions of the year, are a very different problem from the brief gusts or squalls which accompany the onset of the rains in many mainland areas. These latter often constitute the banana planter's chief source of loss. It is not uncommon for an area of 1,000 acres or more to be blown flat to the ground in half an hour's time by one of these squalls. This means not only the loss of all profits for about twelve months; it also means increased maintenance costs, since grass springs up quickly when shade is removed from the surface of the land.

While various sorts of protection against blowdowns have been tried, nothing has been found which growers, in general, have considered satisfactory. The best that can be done is to familiarise oneself with conditions in advance of planting, and stay out of those areas where frequent, severe blowdowns must be expected.

Strong, steady winds, such as the trades which sweep across the south side of Jamaica during several months of the year, usually lack sufficient force to blow over plants even when they are carrying heavy bunches of fruit. These winds do, however, have an unfavourable influence on the crop through reduction of the leaf surface resulting from whipping of the leaves. In more exposed areas this may become a serious matter.

Soils.

Beyond all doubt, the ideal soils for bananas are the clay loams and fine sandy loams, six feet or more in depth. Fine sandy loams are relatively rare except along the banks of the larger tropical streams, where they occur in narrow zones extending back from the streams a distance of a few hundred yards. They then usually become gradually heavier, until they change to heavy clays, which are the least desirable of all banana soils. Clay loams are more abundant; they occur over large areas in many of the principal banana regions.

It must be emphasized, that soils are not satisfactory unless deep. The best sandy loam or clay loam, if it changes to sand or gravel at a depth

of less than a foot and a half, should be avoided; and, to be good, it should be three feet or more in depth. Similarly, a loam underlaid with stiff impervious clay is bound to give trouble.

The class of soils which presents the most problems to the banana planter is the large and abundant group of clays, some of which occur in practically every important banana growing region. In recent years, however, much progress has been made in the study of these soils, with the result that clays, which 20 years ago would have had to be abandoned, are now being farmed profitably. The main reasons for this, I believe, are three:—

1. The importance of adequate drainage has at last been appreciated.

2. It has been realized that the surface must be kept free of grass.

3. Usefulness of tillage in connection with handling certain types of clay has been demonstrated.

Soils are commonly classified by their texture; that is to say, by the degree of fineness exhibited by the particles of which they are composed. In many ways this is a satisfactory classification; it is easy to use and can be applied to all soils regardless of origin. It has, however, one serious drawback when employed in conjunction with the study of clay soils. It cannot take into account factors other than texture; hence, for example, it throws together in one group, termed light clays, all soils containing from 30 to 50 per cent. of clay; and in another group, called heavy clays, all soils containing more than 50 per cent. Now, in actual practice there are some soils which fall in the light clay group but which, from the planter's standpoint, are much harder to handle than some of the heavy clays. The planter must therefore ask himself, "What sort of clay is this?", rather than, "How heavy is this soil?". There are alluvial soils in Honduras containing from 65 to 85 per cent. of clay, which are excellent banana lands requiring nothing more than ample drainage to produce good fruit. There are other soils analyzing not more than 50 per cent. clay which have so far defied all efforts to make them produce good fruit on an economical basis. To the prospective planter probably no more valuable advice than this can be given: if your lands are mainly clays, try them out on a small scale before planting extensively.

One of the worst of all banana soils—in fact it should hardly be termed banana soil at all—is one which by analysis is called sandy clay. This is a mixture of sand and clay, the character of which is perhaps best described as "crude" or "harsh". When exposed to the sun, it bakes like cement and, even under the most expensive treatment, it cannot be made to produce good crops of first-class fruit.

Drainage.

I believe it is safe to say that the greatest single advance which has taken place in the banana industry in the past quarter of a century has been that with respect to drainage. The prospective planter cannot give this subject too much attention, upon it depends, in the majority of cases, his success as a producer of bananas.

To grow satisfactorily, the banana plant should have at all times at least three feet of water-free soil in which to develop its root system; that is to say, there should at no time be standing or free water in the ground closer than three feet to the surface. Naturally, it is not possible to achieve this ideal state of affairs if the land is subject to occasional flooding, but in this case, drainage must be such that water can run off the land as soon as the floods recede and the water table in the soil itself be rapidly lowered to three feet or more below the surface, by drains provided for this purpose.

The problem of drainage must be viewed in a broad way if it is to be attacked successfully. It can well be considered under three separate headings, as follows:—

1. *Adequate Outlet.*—By this we mean that the water, once removed from the area under cultivation, can flow away until it is finally dumped in some place where it can do the planter no harm. If the land which it is desired to plant lies close to the sea, and its surface is only 20 inches above the level of the latter at high tide, then there is no outlet, because it is physically impossible to lower the water in the soil more than 20 inches. Similarly, if the land lies along a stream and certain areas are only two feet above the water in the stream, these areas have no adequate outlet for drainage and cannot be planted.

2. *Good Run-Off.*—Having provided an outlet which will permit the land to be drained, the second point to be given attention is run-off. In other words, is the terrain such that water will nowhere stand upon it for a long enough period of time to injure banana plants? On light, porous soils little run-off needs to be provided. If there are low spots which catch water, the porous character of the soil allows it to seep through to lower levels very promptly. On heavy soils, however, any low spots which collect water will usually hold it for several days, and this, in turn, will cause serious damage to banana roots. Such spots must be tapped with shallow drains which will take the water out of them immediately and dump it in the main drainage system.

3. *Sufficient Deep Drainage.*—Even in areas which have porous soil and no run-off problem, it will sometimes be found that the water table stands within a foot or two of the surface for long periods of time. This is ruinous to bananas and must be remedied by providing deep drains at necessary intervals so that the water table will never rise within the root zone.

This is undoubtedly the most difficult, as well as the most important, feature of the entire drainage problem. In the first place, it requires detailed observation by means of borings or test wells to determine the behaviour of the water table; and in the second place, it requires an understanding of the soil to know how and where to put drains so as to achieve the desired lowering of the water table.

A six foot length of pipe or a few joints of concrete or clay tubing can easily be placed in the ground so that by frequent observation the rise and fall of the water table can be ascertained. The best way to get full information is to run a line of these tubes between two existing drains or low areas. The tubes can be spaced conveniently, but need not be less than 50 and rarely should be more than a hundred feet apart if the object is to study drainage requirements in detail. Daily or weekly observations should be made and plotted on a profile chart. Connected by a solid line, the readings for any given day will then show the exact location of the water table in relation to the surface of the land, which latter also is represented by a line across the chart. It will be noted that the water table between two drains is rarely flat but rises toward the centre of the interval. This is the critical point and any drainage planned must be deep enough to keep the water out of the root zone in the area farthest removed from the drains.

The arrangement of the drains depends largely on the slope of the land and the nature of the terrain. It conforms to standard drainage practice as described in text books on the subject, hence need not be discussed in detail here. In many cases, a contour system of drainage will prove best. This is particularly true where irrigation is not practised. On the other hand, where the land is fairly level and it is desired to avoid interfering with irrigation as much as possible, drains can be run satisfactorily on straight lines. The depth of drains is sometimes limited by the outlet, but where feasible should rarely be less than 4½ to 5 feet. With this depth, drains can be spaced on sandy soils as much as 300 feet apart, whereas on heavy clays half this distance may be necessary. It is customary to dig drains with a bottom width of one to two feet. The side slope naturally depends largely upon the texture of the soil. In heavy clays a slope of ½ : 1 is often adequate; on clay loams and sandy loams ¾ : 1 is more commonly used, while in light soils a slope of 1 : 1 is occasionally necessary. Soil removed from the drains should be thrown well back from the edges of the latter and frequent openings should be left in the spoilbank so that water can freely run off of the land into the drains.

Drains must be cleaned at least once a year, sometimes twice, and must be resunk once a year to keep them down to their original levels. Carelessness in allowing drains to fill up, ruins their usefulness and is one of the worst sins of the banana planter.

(*To be continued.*)

ORIGIN OF MAIZE.

There have been three general theories regarding the origin of maize: (1) that it originated from pod-corn, *Zea mays tunicata*, which differs from normal maize primarily by a single dominant gene governing the development of a brittle disarticulating rachis and the production of prominent glumes enclosing the seeds; (2) that maize originated from teosinte, *Euchlaena mexicana*, a wild grass native to Guatemala and Mexico, by direct selection, by large-scale mutations or by the hybridization of *Euchlaena* with a grass now unknown; (3) the *Zea*, *Euchlaena* and *Tripsacum*, the three American *Maydeae*, have descended along divergent and independent lines from a remote ancestor.

New evidence from cytogenetic studies at the Texas Experiment Station suggests that *Euchlaena* has had no part in the ancestry of maize, but is instead the product of natural hybridization of *Zea* and *Tripsacum*. *Euchlaena*, which is intermediate between *Zea* and *Tripsacum* in many characteristics, differs genetically from *Zea* primarily by four segments of chromatin all of which have genes with *Tripsacum* effects. Hybrids of *Zea* and *Tripsacum* have shown that there is some association between chromosomes of the two genera and that interchanges of chromatin may occur. The combined data agree in pointing to the comparatively recent origin of *Euchlaena* as the result of natural hybridization of *Zea* and *Tripsacum*.

With *Euchlaena* eliminated from a rôle in the origin of maize, it is reasonable to assume that maize originated as a mutation from a wild pod-corn once indigenous, and perhaps still to be found, in the lowlands of South America. The primary centre of domestication probably occurred in the Andean region of Peru and Bolivia.

The hybridization of *Zea* and *Tripsacum* which occurred when two genera were brought into contact with each other in Central America, gave rise not only to the new genus *Euchlaena*, but also to new forms of maize which spread in both directions, almost completely replacing pure maize in all regions except the Andean. Cytological evidence on chromosomal knobs supports the view that almost all modern maize varieties are contaminated with *Tripsacum*.

The evidence from history, geology, palaeobotany, archaeology, ethnology, morphology, genetics and cytology appears to be in harmony with this new interpretation.—(*Nature*, 1940, 140, p. 338.)

The Editor requests that any subscriber who fails to receive *Tropical Agriculture* regularly should communicate with him immediately in order that the matter may be rectified.

INVESTIGATIONS ON THE NUTRITION OF *COFFEA ARABICA* L.*

[*Note: This article is based on two reviews of a paper by J. C. s' Jacob entitled Voedingsphysiologische Onderzoekingen bij Coffea arabica L, published in the "Archief voor de Koffiercultuur", XII, 1938, pp.* 1-48 *and on some notes in the "Third Annual Report of the Lyamungu Coffee Experimental Station,* 1936." *The original of the first article was not available but a full summary was published in "Die Ernahrung der Pflanze," XXXV, pp.* 115-18, 1939, *and some additional notes were obtained from the abstract in the "Review of Applied Mycology," XXXIII, pp.* 21-22, 1939.]

In temperate countries a great deal of work has been done to study the effect of depriving plants of various elements with a view to revealing the symptoms produced by deficiencies, so that such symptoms may be used as a guide to the plants' requirements. Results of very great value have been obtained in this way for fruit trees. The usual method is to grow young plants either in water culture or in sand culture where the various mineral elements supplied can be carefully controlled. The results of such culture experiments can only be used with caution; and more as a guide to the identification of deficiencies or as a means of discovering the importance of minor elements in nutrition than as a direct guide to manuring practice. It is, of course, understood that plants will frequently respond to manures without any preceding signs of deficiencies.

In Java and East Africa, the technique of water culture and sand culture has been applied to the study of the same problem for *arabica* coffee. It was found that in a suitable culture solution coffee seedlings would develop very well for several months, but the Java results indicated that the culture solution used must be acidic and must contain a good supply of iron. Experiments with a number of neutral or weakly acidic culture solutions showed them to be unsuitable, as symptoms of iron deficiency rapidly appeared even when iron humate was added to the solutions. Only in a solution devised by Shive with an acidity of pH 4.5 did the plants develop normally. The iron deficiency showed itself as a typical chlorosis; the leaf colour became yellowish while the veins still retained the normal green tint.

In the early experiments in Java, it was clearly shown that coffee requires a supply of *boron*. If this element was absent, the plants developed small narrow *apical* leaves with brown markings which later blackened and dried up. This was followed by the death of the leaf buds. Small shoots originated in the axils of the upper leaves, but these also developed the same symptoms. In the East African experiments, plants which received a special nutrient mixture containing boron, manganese and copper, in addition to the usual plant foods, showed generally a larger development than those which did not receive these minor elements. No remarks were made with respect to any special symptoms in the absence of copper, manganese or boron.

In recent years, much information has accumulated on the importance of boron to plants and several diseases have been shown to be due to boron deficiency. Whether coffee would respond to applications of boron remains to be investigated, but if it should, it is unlikely that more than a couple of pounds of borax per acre would be required. Boron is one of those elements in plant nutrition for which the border line between safety and injury is very narrow.

Of the major elements absorbed by the plant, studies were made in Java of the symptoms developed when nitrogen, phosphoric acid, potash, calcium, magnesium and sulphur were withheld. In East Africa, the studies were restricted to deficiencies of nitrogen, phosphoric acid and potash. Observations were also made in Java on the effects of an excess of some of these plant nutrients. Most of the symptoms described in this article were recorded by s'Jacob in Java. The details available of the East African work are less complete, but with one exception, they agree in all essential points with those from Java.

The effect of withholding *nitrogen* were, as might be expected, very far reaching. Within a month of transference of the young coffee seedlings to the culture solution without nitrogen, the check to growth was visible. Both root and shoot development was severely checked, but more so in the case of the shoots. The leaves produced were small and uniformly yellowish (differing from iron deficiency symptoms where the veins retain a green colour), and later an orange brown discolouration developed. It seemed that younger leaves were developed at the expense of older ones, the latter dying off as the former were produced. It is stated that typical symptoms of this kind have been noted in the field. In studies with different amounts of nitrogen it was found that at low concentrations, roots were long, thin and very little branched whereas at concentrations above normal the development was reversed.

In contrast to this, the absence of *phosphoric acid* produced no visible symptoms, though it is pointed out that the normal dark green colour of coffee leaves would prevent the easy recognition of the usual sign of the deficiency of phosphorus (*i.e.* the development of very dark green foliage). In both the case of this plant food and of potash (which will be dealt with later), it seems that either the

* Abridged version of an article by W. W. Mayne published in the *Planters' Chronicle*, XXXV, No. 16, pp. 327-330.

supplies contained in the seed or those absorbed in germination and preliminary growth before supplies were withheld, were sufficient for normal development for the comparatively short duration of the experiments. Similar results were obtained in the East African experiments. On the other hand, in some trials carried out with coffee in pot culture in Munich, it was a deficiency in phosphoric acid which showed the most striking features (Nicklas, H. and Schropp, W., *Tropenpflanzer*, 1931, 34, pp. 269-77). Naturally, the absence of symptoms in these experiments cannot be regarded as an indication of a lack of need of these food materials. Excess of phosphoric acid also produced no definite symptoms in the experiments carried out.

As already indicated, lack of *potash* showed no very marked symptoms in Java, though there was slight check to growth. In order to get over the difficulty introduced by the supplies of this element present in the seed or taken in prior to experimental treatment, coffee seeds were germinated in a poor volcanic sand and transferred, before the expansion of the cotyledons, to the culture solution minus potash. Shortly after transference, the remains of the seed were removed and a few days later, the cotyledons were cut off. In this way the potash content of the seedling was reduced as much as possible. Better results were obtained in this way, but symptoms did not appear until the end of three months. These symptoms consisted of small light yellow spots around the leaf margins, which rapidly turned greyish brown. This marginal injury was separated from the healthy leaf tissue by a light yellow coloured zone. This type of leaf rim injury is a very common symptom of potash deficiency in many plants and was noted in the field at one place in Java. Pot tests with maize revealed a very marked potash deficiency in the soil in question. In the East African experiments, on the contrary, potash deficiency symptoms were the first to develop, being visible as early as 16 days after the commencement of the treatment. These were similar in essentials to those recorded by s'Jacob. The difference in the results with respect to this element cannot be readily explained on the information available on the experimental methods used in each case. It may serve, however, as an instance of the difficulties of this type of work. Excess of potash caused no very marked symptoms beyond a check to growth and some pale spotting of the leaves, rather suggestive of iron chlorosis. The leaves of such plants died prematurely.

Calcium deficiency was the quickest to show up, the first symptoms—a death of the root tips—becoming visible 14 days after the commencement of the treatment. Later a marked reduction in the length of the aerial parts occurred and the leaves curled and became a yellowish green with localised brownish patches. Following this, the apical bud died off and, though new shoots originated in the upper leaf axils, these developed the same symptoms. An excess of calcium, if given in the form of calcium chloride, only slightly retarded growth without the development of any marked symptoms. If the calcium was given in the form of calcium carbonate, however, the results were quite different. A severe chlorosis developed which was undoubtedly due to a deficiency of *iron*. The decrease in acidity caused by the calcium carbonate had reduced the availability of iron in the culture solution. While results from water cultures must be treated with reserve, these observations suggest that the iron availability in the soil is very important to coffee, and soils on the alkaline side may interfere with the intake of this important element, if the alkalinity is due to excess of lime. At the same time, the buffering action of most soils is such that additions of lime at ordinary rates alter the acidity only slightly. The mere presence of iron in the soil even in considerable quantities is not necessarily sufficient to provide the plant with adequate supplies, as has been clearly shown in the case of pineapples in Hawaii and Porto Rico, where in manganese soils and calcareous soils respectively, iron deficiency symptoms appeared which were not corrected by simple addition of iron salts to the soil.

The absence of *magnesium* also caused quite definite and characteristic symptoms. The leaves showed small white to greyish spots concentrated in a zone about two-fifths of an inch from the leaf edge and the tissues within this region were flaccid while those without were turgid. The symptoms appeared after three to four months and as the older leaves dried off, the younger ones developed the symptoms. In addition to the leaf symptoms, root development was poor. Excess of magnesium caused very serious injury; growth was checked, the stem was thin and sometimes showed signs of rotting at the base, the leaves were small and pale and later developed an interveinal chlorosis, and the roots were short, thick and slow growing.

If *sulphur* was omitted, growth was checked, and the general development was rather poor but not so markedly as when nitrogen and calcium were omitted. There was no sign of chlorosis such as are associated with sulphur deficiency in tea.

There are considerable difficulties in applying the results of experiments of this type to field conditions, especially as they are not always concordant and in any case are concerned with conditions entirely different from those experienced by a plant growing in ordinary soils. As a general rule, shortages of such elements as boron, magnesium and sulphur are not very probable and seldom need to be applied artificially.

The most interesting points of practical importance arising from these experiments are *the necessity for adequate supplies of calcium, the sensitiveness of the coffee plant to iron deficiency, the intolerance shown to alkaline conditions and the importance of boron.*

These experiments were all conducted with young plants, and do not afford any information on the requirements of the cropping plant.

AN EXPERIMENT IN THE PROPAGATION OF THE KOLA.

By L. H. Saunders.
(*Agricultural Superintendent, Gambia.*)

Owing to the comparatively low rainfall, the long, unbroken dry season of seven to eight months and the sandy condition of the soil in the Gambia, the culture of the cultivated kola, *Cola acuminata*, can only be successfully undertaken in the low lying regions where there is an abundance of soil moisture all the year round and where there is a high proportion of clay and silted soil.

The wild kola, *Cola cordifolia*, thrives under the severe conditions of the arid regions of the country and this suggested the experiment of grafting the cultivated kola on to the wild kola. No references to this method of propagating kolas could be found in the available textbooks and literature and it is thought to be a new one.

The experiment is only in its early stages but the successful grafting of the two kolas may be of interest to other workers in regions similarly situated to the Gambia.

The method of grafting undertaken in the experiment was the approach (inarching) method, a method easy to perform and suitable to arid conditions. The African peasant of average intelligence could be taught the method in a very short time.

Yearling seedlings of the wild kola were obtained from beneath vigorous growing mature trees in the arid regions and were transplanted into baskets fashioned over a ten-inch pot. The soil used in the basket was one of equal parts good average sandy garden soil and well rotted leaf mould. When the seedlings were established in the baskets (about two months after transplanting) grafting was commenced. Seedlings of both varieties about 15 inches high and with a stem thickness of $\frac{5}{8}$ to $\frac{7}{8}$ of an inch were selected for grafting.

A portion of both scion and stock was removed, brought carefully together, the cut surfaces fitted into one another and secured with a bandage of raffia. No grafting wax or other protective material was used (the grafting operation being undertaken in as simple a form as possible for peasant farmers to follow). During the period of union of scion and stock the plants were kept under light shade and given a weekly ration of one cigarette tin full of liquid manure solution.

The scion was kept on the parent plant for a period of four weeks after which time union was complete, it was then severed from the parent plant. Two weeks after severance of the scion the terminal shoot and all side shoots or buds of the stock were cut or rubbed off. Active growth of the scion began six to eight weeks after severance from the parent plant.

After six months the twenty original grafted plants showed healthy growth and were planted out into their maturing sites.

The grafting operation was undertaken in January two months after the cessation of the rains and five months prior to the commencement of the rainy season. This is a period when the peasant farmer of the Gambia would have sufficient relaxation from farming operations to undertake the work of grafting himself.

POTASH FROM SEA WATER.

Although it has been found possible in many instances to recover the potash content of natural lake brines, the low percentage of potassium salts and the huge preponderance of sodium chloride in sea water have hitherto prevented direct recovery of potash from the latter source. Potassium salts of varying degrees of purity can, however, be obtained from the "bitterns" produced in the evaporation of sea water for the production of common salt. It is evident that a process for the separation of potassium salts from the enormously larger amounts of sodium compounds present in sea water might be based very conveniently on a selective precipitant which would give an insoluble potassium compound while leaving the sodium salts in solution. Such a compound, as an analytical reagent for the detection of potassium on a very small scale, was proposed by Poluektov, the reagent being dipicrylamine or hexa-nitro-diphenyl-amine, which gives an insoluble orange-red potassium compound in a slightly alkaline solution.

The use of dipicrylamine has now been applied to the recovery of potash from sea water, and a patent has been taken out by the Norsk Hydro Elektrisk Kvaelstof, A.S. All the metals, except potassium, present in sea water form soluble compounds with the reagent. In the application of the process, one of the soluble salts of dipicrylamine, preferably the calcium compound (although the sodium, magnesium, or lithium salts may be used), in slightly alkaline solution, is added to sea water or other saline solution in quantity a little below that theoretically required to react with all the potassium present. The insoluble potassium salt is precipitated, filtered off and washed. The filtrate is acidified in order to precipitate any unused reagent, which is recovered. The insoluble potassium dipicrylaminate is treated with an acid, preferably nitric acid, giving a solution of potassium nitrate and precipitating the dipicrylamine, which is recovered for re-use. Sulphuric, hydrochloric or acetic acids can also be used, while by the employment of carbon dioxide under pressure, potassium carbonate can be obtained.

An experimental plant is stated to have been erected at the Heroya works of the Norsk Hydro Elektrisk Company.—(*Bulletin of the Imperial Institute*, Vol. XXXVIII, No. 2, pp. 247-248, 1940).

ROOT ACTIVITY AND OXYGEN REQUIREMENT IN RELATION TO SOIL FERTILITY.*

LIFE may be regarded as an unstable equilibrium maintaining itself on energy obtained either directly from sunlight or indirectly by the oxidation of carbohydrate or other substances which yield energy on oxidation. The importance of the energy relationships of a number of life processes in plants has stimulated research by a number of investigators. Energy released during aerobic respiration of most substances is much greater in quantity than that released during anaerobic respiration, so that factors influencing aerobic respiration are very important in processes involving energy relationships. The rate of aerobic respiration is most commonly limited by the oxygen supply, the concentration of carbon-dioxide in the medium, and the amount and availability of oxidisable food material. Experimental evidence indicates that a given rate of respiration can maintain only a definite amount of protein, that release of energy is necessary for absorption of water by plant roots, and that part of the energy released during respiration greatly facilitates transportation of water within the living plant. The size and productivity of the aerial parts of the plant are governed to a large extent by the size and activity of the root-system, and this in turn is controlled by the physical, chemical and biological nature of the soil. The soil is not a static system, but undergoes changes due to the presence of living organisms, the presence of decomposable substances, and the action of external influences, such as temperature, moisture and oxygen supply. These changes are reflected in the growth of the plant which the soil supports. Many factors determine soil fertility by their direct or indirect action on the roots of plants. Among these are compactness of soil, pore-space, water content, water-holding capacity, presence and availability of mineral nutrients, amount and nature of organic matter, the reaction of the soil solution and temperature. The great number of factors concerned makes the study of soil fertility a difficult problem, since no one factor can be varied without changing many of the others.

The activity of the soil micro-organisms is controlled to a great extent by the amount and character of the organic matter, as well as by the temperature. With increased activity, oxygen is used up and carbon-dioxide produced, so that, under suitable conditions, the micro-organisms may become so highly active as to impose anaerobic conditions on the soil. This may adversely affect the roots of most plants, by inducing a lack of oxygen, by creating a high carbon-dioxide content in the soil air, and by giving rise to products of incomplete metabolism by soil micro-organisms; thus, poor growth is characteristic of most plants growing under anaerobic soil conditions. The oxygen supplying ability and the amount of oxygen in the soil depend on various soil characteristics. The oxygen supplying ability has been found to vary with moisture content and compactness, and to be greatest in loosely-packed, dry soils.

A review of the literature on the rôle of oxygen in root activity indicates that it is now generally accepted that all organs of plants respire, and that roots respire in exactly the same manner as stems and leaves, despite the difference in the environmental medium. This fact is supported by evidence drawn from observations on germination, the early stages of which concern the seedling radicle. Thus, it has been found in investigations of oxygen concentration in relation to the growth of apple tree roots that, when the oxygen in the soil is maintained at three per cent. concentration, the roots are at a subsistence level with regard to oxygen, that is, they are alive but grow only slowly, if at all. It is also reported that absorption and accumulation are probably inhibited at oxygen pressures below ten per cent. oxygen concentration. Specific studies on the respiration activity of the roots of wheat seedlings have led to the conclusion that respiration activity consists of two parts, namely, basal respiration necessary for the maintenance of roots and for growth, and anionic respiration, which supplies energy for absorption of anions. Of these two, basal respiration is always aerobic, whereas anionic respiration may be anaerobic. If, therefore, the oxygen content of the soil is so low as to be insufficient for basal respiration the roots will die, and death of the tops will soon follow. If the reduction is not sufficient to cause death, but sufficient to impair the growth of the roots, this condition will be reflected in reduced growth and productivity of the aerial parts of the plant.

The relation of soil oxygen to soil organic and nitrogen content and to the growth of wheat seedlings was determined in the investigation. To a soil prepared from two parts of garden loam mixed with one part of sand, various quantities of starch and ammonium sulphate were added. The plants were grown under uniform and controlled conditions of light, temperature and moisture. The wheat grains were germinated at room temperature, selected for size, and planted out when the coleoptile was 15 cm. long. The experiment comprised five pots containing six plants each. The data and results are shown in Table I.

Soil core samples were taken from the pots for analysis on the 6th and 12th days, using a cork borer as sampler. It was found possible, on account of the small variation, to use only one of the pots for the oxygen determination, so that growth in the other pots was not disturbed.

* From an article by Kenneth S. Karsten in the *American Journal of Botany*. Vol. XXVI, December, 1939, pp. 855-860.

TABLE I.—*Effect of organic matter and nitrogen on the oxygen content of soil and on the growth of wheat seedlings*

Percentage starch.	Percentage $(NH_4)_2SO_4$.	O_2 content per kilo of soil. Sixth day. ml.	O_2 content per kilo of soil. Twelfth day. ml.	Growth of wheat as fresh weight of tops in mgm. per 6 plants.
0.00	0.00	8.961	7.000	977.6 ± 92.2
0.00	0.33	3.844	2.180	580.7 ± 30.4
1.67	0.00	1.102	0.788	290.1 ± 143.8
0.33	0.33	4.278	1.548	439.2 ± 106.9
1.00	0.33	3.000	0.000	Dead on 12th day
1.67	0.33	1.333	0.000	Dead on 11th day
3.33	0.33	0.000	0.000	Dead on 7th day
6.67	0.33	0.000	0.000	Dead on 7th day

The results of this investigation show that oxygen content varies with soil type, water content, and with nitrogen and organic matter contents. Other factors, such as carbon-dioxide content, may also exert an influence. That the lowered oxygen content was caused by the increase in the activity of the soil micro-organisms was shown by the fact that the appropriate soil mixtures supported profuse fungus growths. The results may not be directly comparable to field conditions, as it is suspected that there would be so great a variation that a large number of samples would be required. The added organic matter and nitrogen allowed such an increased growth of micro-organisms that the oxygen content of the soil was abnormally reduced. Diminished growth was caused by abnormally low oxygen contents, and when the oxygen content reached zero, the plants soon died.

H.A.Mc.K.T.

UNSOLVED PROBLEMS OF AGRICULTURAL CHEMISTRY.*

FOR the purposes of this discussion agricultural chemistry is defined as that branch of chemistry which treats of the chemical composition and mutual chemical relationships of soils, fertilizers, crops and farm animals. The industrial utilization of agricultural produce beyond the frontiers of the farm falls outside the scope of this definition. Among the agricultural chemical problems requiring more intensive investigation the following are mentioned :—

Improved Methods of Chemical Analysis.

Since the time of Lavoisier progress in agricultural chemistry has advanced in strict proportion to improvements in the art of chemical analysis. This is especially demonstrated in the present era when the application of more refined chemical, physical and biological methods of analysis has established the recognition of the importance of minute traces of hitherto neglected mineral elements and of the almost intangible organic agencies such as vitamins, enzymes, auxines, viruses and hormones. It may be asserted with confidence that future progress in agricultural chemistry will depend upon effecting still greater improvements and refinements in analytical methods of research.

Composition of the Aqueous Fluids in the Tissues of Crops.

In the analysis of the sugar cane, sorghum and other crops, conventional estimates are made of the composition of the so-called "normal" or total juice, whereas actually there occur in each plant not one but many saps or juices—as those of the vacuoles, the cytoplasm, the ducts, nectaries and other organs, each with its own peculiar composition. The micro-analyst, by investigating the composition of each of these cellular juices, will help greatly towards solving a number of important neglected problems that relate to the chemistry of crops and to the best methods for their utilization.

Effect of Environmental Influences on the Yield and Composition of Crops.

More investigations are needed to evaluate the respective influences of soils, fertilizers, cultivation, rainfall, temperature, altitude, sunshine and other environmental factors on the yield and composition of crops. Variations in yield and composition have been attributed to differences in soil and fertilizer, when the determining factor was climate. The best method of ascertaining the degree of climatic influences is by means of soil-exchange experiments. It has been found, for example, that wheat grown on a Maryland soil in Kansas contained six per cent. more protein than the same variety of wheat when grown on the same soil in Maryland. The predominance of climate over soil has also been demonstrated by soil-exchange experiments with sugar cane in the Hawaiian Islands.

Distribution of Mineral Elements in Soils, Crops, and Bodies of Farm Animals.

It is a strange anomaly that, in their study of the human, animal, plant, and mineral worlds, chemists have usually selected problems in the inverse order of their immediate concern. The relative abundance of some fifty elements in the rocky crust of the earth has been carefully tabulated upon the basis of thousands of analyses while only rough compilations have been made of the abundance of some 20 or 30 elements in the average soil. In the case of plants the

* Article by C. A. Browne reprinted from *Chronica Botanica*. VI, 1, 1940.

obsolete tabulations of Wolff, which are still the most complete that are available, give the abundance of only nine of the common mineral elements occurring in crops. As for the composition of the mineral matter of animals and man, only a few very rough tabulations of the more important elements are available, exact information on the relative abundance and distribution of the minor constituents being almost wholly lacking. The filling of these gaps in our knowledge and the extension of such information to a study of the mutual relationships of the mineral elements of soils to those of crops and animals under different environmental conditions belong to some of the major unsolved problems of agricultural chemistry.

Improving the Nutritive Value of Crops.

Proposals have been made to increase the content of nutritive mineral elements in crops by special methods of intensive fertilization. The mineral content of crops can be modified within certain limits in several ways. Different varieties of grains and vegetables vary in their capacity for assimilating different elements from the soil. The production of crops with a preponderance of certain mineral nutrients might be advantageous for certain requirements provided there was not a corresponding diminution of some other essential nutrients, as frequently happens. Caution must be exercised in the employment of patented mineralization formulas for so many factors influence the composition and nutritive value of crops that a special scheme of fertilization adapted to one locality might be highly detrimental in another situation.

Deterioration of Agricultural Products.

The losses from the deterioration of raw and manufactured agricultural products during storage and transportation amount each year to a sum of colossal proportions. The rôle of micro-organisms enzymes and atmospheric influences has been extensively studied in this connection, but a fourth highly important agent of deterioration, *viz.*: the undesirable chemical changes which take place within the product itself, has been generally overlooked. Examples of such internal chemical changes are the darkening of sirups, honey and other food products as a result of slow combinations between sugars and amino acids (the so-called Maillard reaction). Haystacks catch fire spontaneously and tanks of sugar cane molasses sometimes undergo spontaneous heating and carbonization as a result of obscure chemical reactions that take place within the product itself. The nature of these spontaneous chemical changes in our agricultural products constitutes a very important unsolved problem.

Economic Problems of Agricultural Chemical Significance.

Economic problems of national importance frequently arise and to many of these agricultural chemists are the only ones qualified to give a decisive answer. Politicians in America and other countries have debated the question "Is the sugar beet an economic crop?" Judged alone by the comparative costs of producing beet sugar in temperate zones and cane sugar in the tropics, the sugar beet appears to be a very uneconomic crop, but when the great improvement of the surface soil produced by growing a deep rooted rotation crop, such as the sugar beet, is considered, together with the greater productive power which the beet gives to the soil for succeeding crops and the great stock-feeding value of the beet leaves, pulp and molasses, the balance of chemical evidence is that the sugar beet is a very economic crop wherever it can be successfully grown. The indirect economic benefit or injury of farm practices is too often overlooked. It is a subject to which agricultural chemists should give greater consideration.

GENETICS AND PLANT BREEDING.

J. B. Hutchinson (*J. Genetics*, 40, 271-282, 1940) has discussed the influence of genetics upon plant breeding. He shows that the introduction of proper statistical methods and progeny-row testing greatly facilitates the work of the breeder and provides a more efficient selection method than mass-selection. Using examples from cotton-breeding the disadvantages of pure line methods are contrasted with the results achieved from selection of mixed populations and with the advantages of land races which although impure from the geneticist's point of view remain stable under the influence of selection of the plant-breeder and of the environment. In an accompanying paper, V. G. Panse (*J. Genetics*, 40, 283-302; 1940) provides methods for the analysis of quantitative characters which will be useful in plant breeding. F_2 plants of hybrids between three cotton strains were grown in a randomized progeny trial. Ten plants of each F_2 progeny were selected at random and an F_3 progeny was grown from these in a particular randomized arrangement. It was found that plot differences partly affect the studied character, staple length, therefore the mean value of each plot must be taken into account when selecting plants for breeding. It is shown that it is preferable to select plants on the excess staple length over the mean length of the plot. The variance of the progeny may be split up into that due to genetic influences and that due to environmental influences. The variance due to genetic influences may be used to estimate the number of genes which are controlling the segregation of the character being investigated. The possible number of genes, however, is influenced by their dominance and other inter-relationships. Genetics systems may be set up to satisfy this requirement and thus the probable number of genes which control a particular character may be suggested.—(*Nature*, Vol. CXLVI, No. 3699.)

THE MYCORRHIZAL HABIT IN RELATION TO FORESTRY.*

In a recent series of papers published in *Forestry*, there is described the origin and application of a new and strikingly successful method for promoting growth of young conifers in unpromising soil by the use of composts made from straw, hop-waste and other materials.

Attempts to analyse the causes of failure in an area of poor heathland where afforestation by species of pine was initiated by the Forestry Commission of Great Britain in 1924, led to the view that among factors responsible for the observed infertility must be sought those actively deleterious to growth as well as others already assumed to originate in known poverty in nutrients. The failure of mycorrhizal development that was associated with impaired vitality and poor and irregular growth of the trees was attributed to inhibition of mycelial activity of the appropriate mycorrhiza-formers by unfavourable soil environment rather than to their absence. Assumption that such inhibition is but one expression of abnormality of the soil in question in respect to micro-biological activities led to the use of organic composts of known origin and standardised manufacture designed to bring about qualitative changes in the organic residues and the micro-flora and -fauna associated with them. (M. C. Rayner, *Forestry*, 8: 96, 1934.)

A later paper described details of compost manufacture and placed on record the remarkable and persistent effects brought about by a single application, drawing attention also to the differential reactions given by different species of conifer or by the same species in different soils, to treatment with the same compost. At this stage, the view was expressed that the beneficient action on growth "differs essentially from that of ordinary manures", depending rather upon changes in the humus constituents and their associated biological activities (M. C. Rayner, *Forestry* 10: 1, 1936).

The obvious criticism that the composts themselves supplied appreciable amounts of available nutrients has been met by the use of experimental cultures of pine in transported soil. In these experiments, alternative series of Scots pine seedlings were supplied respectively with two different composts, and two other series with salts containing amounts of lime, available nitrogen, potash and phosphoric acid equivalent to those in the corresponding composts. The results of these experiments, expressed as tables of dry weights with graphs derived from them, and illustrated by photographs, are available in a paper published in 1939 (M. C. Rayner, *Forestry* 13: 19, 1939). They show that the beneficial effect of the composts is far in excess of anything attributable to the contained salts. They also confirm earlier conclusions respecting the existence of deleterious substances in the experimental soil, proving that addition of composts puts an end to the production of such substances, whereas addition of equivalent amounts of inorganic nutrients produces no such effect—a result in conformity with the view that they are of biological origin.

Stimulation of mycorrhizal activity is a notable feature of the renewed health and vigour of the plants growing in compost-treated soil. Marked variation in numbers of mycorrhizas formed and in their structural features are correlated with relatively small soil changes in respect to organic content and amounts of available nutrients, thus indicating that mycorrhizal reaction may serve as a delicate indicator of soil conditions favourable or otherwise to the trees. A full account of mycorrhizal behaviour with the mycological data relating to it is in preparation.

It is not suggested that similar methods can be used as a universal panacea for adverse soil conditions, or that in cases where their use is indicated, the direct method of compost treatment is always practicable on economic grounds. The experiments are held to be significant and their results worthy of attention because of the light shed by them on underlying and little understood causes of soil fertility, and because the interpretation offered of compost action is capable of very wide application. In the special case under review, the treatment is believed to be effective because it operates as a means of biological control setting free dormant soil activities and bringing about profound changes in the organic substrate.

From the standpoint of the plant physiologist, full understanding of soil fertility in terms of plant nutrition and growth is still lacking; the exact rôle of mycotrophy and the mycorrhizal habit is a notable example of such lack of knowledge. New methods of approach to these problems are needed. The experiments described in the papers cited are believed to contribute to this end.

* Article by M. C. Rayner, reprinted from *Chronica Botanica*, VI, 1, 1940.

DETERMINING SOIL MOISTURE.

Plaster of Paris absorbs moisture, and the wetter it gets, the lower its electrical resistance. Dr. George John Bouyoucos of Michigan State College made use of this principle in a handy gadget which tells farmers the moisture content of their fields. Blocks of plaster of Paris the size of safety-match boxes are buried with wires leading to the surface. The wetter the soil, the lower the resistance of the buried blocks. Measurements can be taken by merely hooking the surface wires to a Wheatstone bridge, which measures the electrical resistance. By burying a number of plaster blocks at key locations, a farmer can go around at any time and get a moisture map of his land.—(*Time*, 1940, Vol. XXXVI, Oct. 28, p. 50.)

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Nitrogen in Sugar-Cane Leaf.

A method has been developed by P. H. Yuen and F. E. Hance for diagnosing the nitrogen nutrition of a cane crop, which in outline is as follows: with a ticket punch small disks of green leaf are taken from the leaves attached to the second, third and fourth ligules, the uppermost visible ligule being counted as one; the samples are taken midway of the leaf at its widest point. The leaf disks are dried, and nitrogen is determined by the Kjeldahl method, using a special Nessler reagent for the distillate. Sampling is started with cane about three months old, 10 stalks constituting a sample, and is repeated at monthly or bi-weekly intervals.

From controlled field and pot experiments, it is seen that the amount of nitrogen in the leaf is a function of the amount of nitrogen in the soil. Two general phenomena come to notice; namely, (1) while the total amount of nitrogen absorbed by the plants increases with increased amounts of nitrogen in the soil, the "nitrogen index" of the cane, or percentage of nitrogen in the dry substance of the leaves, decreases; and (2) the more nitrogen in the soil, the larger the growth of the cane as measured by its elongation, *i.e.* the increased nitrogen stimulates the cane to give a greater yield.

From these relations, it appears possible, by sampling and analyzing the cane leaves in the manner described, to diagnose the crop for its nitrogen needs. The procedure is to give the soil an amount of nitrogen that previous experience has indicated to be about normal, and then to start analyzing the young crop. If the analysis indicates a decreasing nitrogen level below a standard figure, the amount of nitrogen in the soil is increased by applying more fertilizer, and this may be continued until the nitrogen content of the leaves shows a rise, indicating "luxury consumption". For P.O.J. 2878, a leaf-nitrogen content around 2 per cent. appears to be about normal up to the age of nine months; during the rest of the growing period the content may be about 1.5 per cent. or slightly more. The method is considered as controlling overall growth (total substance) without taking quality into consideration.—(*Facts about Sugar*, Vol. 35, No. 1, p. 33, 1940.)

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Effect of Green Manuring on Water-Holding Capacity of Soils.

Nine years of continued use of green manure has increased the sticky point of the top 30 cms. of the soil by about 1.25 per cent. (of oven-dry weight of soil). This represents an increase in the field capacity of the soil as a whole, equivalent to about 6 mms. (0.25 inches) of rain, so that green manuring under these conditions is of little importance from the point of view of increasing the water-holding capacity of the soil. Its beneficial effects lie in other directions.

It is a well recognized fact that the water-holding capacity of humus or partly decomposed organic matter is very high when compared with the mineral matter of soils. Thus, on the basis of the oven-dried material, soil humus may have a water-holding capacity of the order of 200 to 300 per cent., or in the case of some "humus" extracts even up to 1,000 per cent., compared with 20 to 40 per cent. for mineral clay soils. For this reason, any method of adding organic matter to the soil, such as green manuring, may be expected to increase the soil's water-holding capacity. However, a consideration of the small amount of organic material left in the soil after the first rapid decomposition has taken place, compared with the total bulk of the root zone of the soil (about 4,000 tons per acre for a root zone of 2 feet depth) would lead one to expect that this increase in the water-holding capacity of the soil following on the successive ploughing-in of green crops annually, is probably rather small.

The influence of the green manure is confined to the first 30 cms. of soil, as one would expect. The slightly lower sticky points of the tick-bean plots below 30 cms. is just significant, and must be explained by assuming that the mean of the soil texture of the tick-bean plots is slightly lower than that of the clean-cultivated plots. That the difference in the mean soil texture of the two plots is only of the order of 2 per cent. is very satisfactory and shows that the soil variation has been largely overcome.

These results show that, under the conditions obtaining, the increase in the water-holding capacity of the soil brought about by continued green manuring is of little practical significance. It must be clearly understood that we are dealing here with the effect of green manuring on the amount of water retained by the soil after it has been wetted by sufficient rain or irrigation water. This is entirely distinct from any effects of green manuring on the structure of the soil, on the permeability of the soil, or on the fertility of the soil.—(Eric S. West and A. Howard in *Journ. of the Council for Scientific & Industrial Research*, 1936, Vol. IX, p. 65.)

LAND PRODUCTIVITY MAP OF TRINIDAD, B.W.I.

Copies (price: 1*s.* per copy, post free) of The Tentative Land Productivity Map of Trinidad referred to in Professor Hardy's article on "A Provisional Classification of the Soils of Trinidad" which appeared in the 1940 August issue of this Journal may be obtained on application to the Editor, *Tropical Agriculture*, Imperial College of Tropical Agriculture, St. Augustine, Trinidad, B.W.I. Separate copies of the Table at 3*d.* each can also be supplied.